PCT/GB 01/01182

The Patent Office

REC'D 0 AY 2001

WIPO PCT

INVESTOR IN PEOPLE

GB01/1182

The Patent Office
Concept House
Cardiff Road
Newport
South Wales
NP10 8QQ

PRIORITY DOCUMENT

SUBMITTED OR TRANSMITTED IN COMPLIANCE WITH RULE 17.1(a) OR (b)

4

I, the undersigned, being an officer duly authorised in accordance with Section 74(1) and (4) of the Deregulation & Contracting Out Act 1994, to sign and issue certificates on behalf of the Comptroller-General, hereby certify that annexed hereto is a true copy of the documents as originally filed in connection with the patent application identified therein.

In accordance with the Patents (Companies Re-registration) Rules 1982, if a company named in this certificate and any accompanying documents has re-registered under the Companies Act 1980 with the same name as that with which it was registered immediately before re-registration save for the substitution as, or inclusion as, the last part of the name of the words "public limited company" or their equivalents in Welsh, references to the name of the company in this certificate and any accompanying documents shall be treated as references to the name with which it is so re-registered.

In accordance with the rules, the words "public limited company" may be replaced by p.l.c., plc, P.L.C. or PLC.

Re-registration under the Companies Act does not constitute a new legal entity but merely subjects the company to certain additional company law rules.

Signed M Cockie

Dated 26 April 2001

Patents Form 1/77

Patents Act 1977
(Rule 16)

THE PATENT OFFICE
F
18 MAR 2000
NEWPORT

The Patent Office

Request for grant of a patent

(See the notes on the back of this form. You can also get an explanatory leaflet, from the Patent Office to help you fill in this form)

The Patent Office

Cardiff Road
Newport
Gwent NP9 1RH

1.	Your reference	P/70038/SF - CJS0367ADT
2.	Patent application number *(The Patent Office will fill in this part)*	**0006514.4** 18MAR00 E522465-8 D02806 P01/7700 0.00-0006514.4
3.	Full name, address and postcode of the or of each applicant *(underline all surnames)*	ALSTOM 25 Avenue Kleber 75795 PARIS Cedex 16,
	Patents ADP number *(if you know it)*	7747769002
	If the applicant is a corporate body, give the country/state of its incorporation	FRANCE
4.	Title of the invention	AN IMPROVED ELECTRICAL SUBSTATION
5.	Name of your agent *(if you have one)*	L. P. Dargavel
	"Address for service" in the United Kingdom to which all correspondence should be sent *(including the postcode)*	Alstom UK Limited P.O. Box 70, Mill Road, Rugby, Warwickshire CV21 1TB.
	Patents ADP number *(if you know it)*	7510944001
6.	If you are declaring priority from one or more earlier patent applications, give the country and the date of filing of the or of each of these earlier applications and *(if you know it)* the or each application number	Country — Priority application number *(if you know it)* — Date of Filing *(day/month/year)*
7.	If this application is divided or otherwise derived from an earlier UK application, give the number and the filing date of the earlier application	Number of earlier application — Date of filing *(day/month/year)*
8.	Is a statement of inventorship and of right to grant of a patent required in support of this request *(Answer 'Yes' if: a) any applicant named in part 3 is not an inventor, or b) there is an inventor who is not named as an applicant, or c) any named applicant is a corporate body. See note (d))*	Yes

P s Form 1/77

9. E..er the number of sheets for any of the following items you are filing with this form. Do not count copies of the same document

Continuation sheets of this form	-
Description	17 + 17
Claim*(s)*	4 + 4
Abstract	1 + 1
Drawing*(s)*	2 + 2

SW

10. If you are also filing any of the following, state how many against each item.

Priority documents	-
Translations of priority documents	-
Statement of inventorship and right to grant of a patent *(Patents Form 7/77)*	-
Request for preliminary examination *(Patents Form 9/77)*	1
Request for substantive examination *(Patents Form 10/77)*	-
Any other documents *(please specify)*	-

11. I/We request the grant of a patent on the basis of this application.

Signature

L. P. Dargavel - Alstom UK Limited

Date

17 March 2000

12. Name and daytime telephone number of person to contact in the United Kingdom — Mr. L. P. Dargavel — Tel: 01788546600

Warning

After an application for a patent has been filed, the Comptroller of the Patent Office will consider whether publication or communication of the invention should be prohibited or restricted under Section 22 of the Patents Act 1977. You will be informed if it is necessary to prohibit or restrict your invention in this way. Furthermore, if you live in the United Kingdom, Section 23 of the Patents Act 1977 stops you from applying for a patent abroad without first getting written permission from the Patent Office unless an application has been filed at least 6 weeks beforehand in the United Kingdom for a patent for the same invention and either no direction prohibiting publication or communication has been given, or any such direction has been revoked.

Notes

a) If you need help to fill in this form or you have any questions, please contact the Patent Office on 01645 500505

b) Write your answers in capital letters using black ink or you may type them.

c) If there is not enough space for all the relevant details on any part of this form, please continue on a separate sheet of paper and write "see continuation sheet" in the relevant part(s). Any continuation sheet should be attached to this form.

d) If you have answered 'Yes' Patents Form 7/77 will need to be filed.

e) Once you have filled in the form you must remember to sign and date it.

f) For details of the fee and ways to pay please contact the Patent Office.

AN IMPROVED ELECTRICAL SUBSTATION

This invention relates to improvements in electrical substations, and in particular to a substation for use in a power transmission and distribution system.

Both heavy industry and domestic users consume increasingly large amounts of electricity. As the electricity is generated in central locations at power stations, there is thus a need to both transmit and distribute electrical power over large distances. This is often referred to as transmission and distribution.

The majority of electrical power transmission uses alternating AC voltages and currents due to the ease at which an alternating supply can be generated and the ability to use transformers to convert the supply voltage from one level to another. DC transmission systems are also used in some cases, especially where power is to be transmitted over very large distances. An example of such a DC system is the cross channel link between the United Kingdom and France which operates at around 500k volts.

For efficiency, the voltages at which power is transmitted in an AC network are necessarily very high. For overhead power cables, in the United Kingdom, transmission at 128k volts,160k volts, 220k volts and 280k volts is common. Of course, different countries use different voltages for administrable and historical reasons. Generally transmission occurs at around 150k volts or more, with distribution below 150k volts. As this is considerably higher than the domestic voltage used, typically 400 volts at three phase, then it is necessary to convert the high voltage to a lower voltage when tapping off power from the transmission line.

Power is taken off the main transmission lines by substations which fall into two main categories: Transformer sub-stations and switching sub-stations.

The transformer sub-stations role is to convert between the very high voltages present on the transmission network and intermediate levels suitable for generator generation and distribution to a specific area such as an industrial estate or housing estate. For example, in the United Kingdom these may typically be required to convert a 220k volt input into a 60k volt output suitable for an urban supply. They are typically located outside of urban areas and act as the first tap onto the network transmission.

The role of the switching substation is simply to direct power from one port of a distribution network to another. Typically this would be to take a tap from a ring distribution network. Switching sub-stations do not generally either step-up or step-down the voltage.

Of course, substations may serve other roles, such as the transmission and distribution of power to a railway network. In general however, a common feature to all substations is that they receive an input at a first voltage and provide an output at a second voltage. The two voltages are usually different in magnitude, but could be of the same magnitude and yet can differ in phase due to transmission delays.

At present, because of the high power levels in transmission and distribution systems the use of ac power is most prevalent as it allows substations to be constructed around a simple transformer to convert voltages from one level to another. These are protected by circuit

breakers so that the transformer can be isolated in the event of a fault and to allow repair to be carried out. To ensure continuity of supply, two transformers are usually provided in parallel, each being connected to the network through circuit breakers so that one can be completely isolated whilst allowing power to be transmitted through the remaining transformer.

To fine tune the output voltage from the transformer one or more tap changers are typically provided. In use the output voltage is periodically monitored and the tap changer moved to add in or remove one or more turns of the transformer winding until the correct output voltage is obtained. Other than this, adjustment in situ is very limited.

As well as their limited flexibility a further disadvantage of transformer based substations is that they are extremely bulky and quite crude in their operation.

A problem specific to transmission networks, which employ overhead lines is that the amount of power which can be passed down the line will depend on the weather conditions as well as the condition of the line (for instance during maintenance). In hot weather the cables will expand and droop towards the ground. This reduces the power that can be passed down the line. Also, more power can be passed down the line on a windy day than on a calm day as the wind helps to dissipate heat produced by the cables. A passive transformer based system, as used at present, requires additional circuits upstream to compensate for these changes if poor flow along the lines is to be optimised.

One device which can be used to optimise power flow comprises a compensator known as a VAR Compensator which introduces a variable

reactance to the line to balance changes in line inductance. Again, this adds to the complexity and the cost of the system.

An object of the present invention is to provide a substation for use in a transmission and distribution network which overcomes, at least partially, some of the problems of the prior art passive substations.

In accordance with a first aspect, the invention provides a substation for use in a power transmission and distribution network comprising:

a single phase isolating transformer having at least one input winding and at least one output winding;

an input solid state switching network comprising a plurality of semiconductor switching devices, the input switching network defining at least one input node for receiving an input voltage from the transmission network and at least one output node connected to the input winding of the transformer;

an output switching network comprising a plurality of semiconductor switching devices, the output switching network being connected to the output winding of the transformer and defining at least one output node from which a voltage output can be taken from the substation; and

a control means adapted to control the operation of the switching devices of the input and output switching networks to generate an output waveform at the output node from the input applied to the input node.

The invention thus replaces the passive transformer based prior art substations with a semiconductor based system in which a control means operates suitable devices to produce an output waveform from an input waveform.

The system may be active in that the control of the switches is dependent upon the condition of the input line and/or the voltage applied to the input.

Preferably, the substation is adapted to operate over input voltages greater than 150k volts, or greater than 100k volts or perhaps greater than 10k volts.

The control means may include measurement means adapted to monitor the condition of the input voltage and modify or generate control signals for the switching devices dependent upon the measured value or values.

The use of such an active control system provides considerable advantages over the prior art. Firstly, it allows much greater control over the output voltage produced. In a passive transformer system, the output voltage waveform is fixed relative to the input by the turns ratio of the transformer. In the substation of the invention the output is no longer dependant in such a limiting way on the construction of the transformer. Indeed, a turns ratio of 1:1 could be used, the conversion being entirely dependant upon the operation of the switching devices.

The input switching device network may comprise a bridge circuit having at least one input node for each phase of the input supply. Typically, three input nodes are envisaged for a three phase distribution network. The input switching network may include a resonant element which forms

a tank circuit, the switching circuit acting to maintain a flow of current in the tank circuit.

Preferably, the transformer comprises a single phase transformer. In a passive prior art system, the transformer must have a transformer phase for each input phase. Hence, for a three phase supply a three phase transformer would have been needed.

Where a single phase transformer is provided, the control means may be adapted to control the switching of the switching devices so that a single substantially sinusoidal waveform is generated in the input side of the transformer whilst the switching devices on the output side of the transformer are operated to reconstruct one or more output waveforms of different phase from the transformer output.

In a most preferred arrangement, the control means is adapted to control the switching devices so as to produce at least one output voltage waveform which is independent of the input voltage waveform. Thus, a clean output waveform could be produced from a noisy input waveform. This obviously cannot be achieved using a passive transformer substation which would faithfully reproduce the input noise in the output waveform.

The switching devices may be arranged in relation to the transformer so that in the event of a failure of one or more switching devices or of the transformer or of the control means then power is not transmitted across the transformer. This acts as a fail safe arrangement. In one construction, a fail safe mode could be achieved by forcing all the switching devices to the same state, isolating the input waveform from the transformer.

The control means may be adapted to control the switching devices, at least of the input switching network, in such a way as to match the input impedance of the substation to the source impedance of the supply line. This maximises power transfer from the supply line, and effectively eliminates the need for a separate VAR compensator which would be needed to achieve the same result with a passive transformer based system.

The source impedance may be controlled in real time by modifying the switching state of one or more of the switching devices under the control of the control means. Means may be provided to monitor the input (source) impedance and the control means may be responsive to this.

The control means may be adapted to control the switching devices to generate an output waveform that differs in phase from the input waveform. This could be adapted to gradually alter the phase of the output over time, for instance to match the output waveform to the demands of a load.

In another refinement a limiting means may be provided which is adapted to reduce the output voltage produced if the current drain exceeds a preferential maximum level. This can be used to temporarily allow the voltage to dip if an excess load current is drawn. The limiting means may comprise means adapted to monitor the output current drawn by the load and means adapted to modify the control signal applied to the switching devices to reduce the output voltage if the current exceeds a threshold value.

The degree of sophistication of the system can be varied to provide various limiting controls. In one arrangement the control signals may be

modified in response to a measure of the rate of change of current drawn. This can allow the system to mimic the action of a fuse.

The provision of the solid state substation can be used to provide several novel arrangements of distribution network.

Thus, in accordance with a second aspect, the invention provides a transmission and distribution network comprising a transmission line for the transmission of electrical power from a generator, a substation in accordance with the first aspect operatively connected to the transmission line, and one or more distribution lines connected to the output of the substation for onward supply of power to a load.

By load we may mean a direct load such as a motor or furnace, or perhaps another substation or part of another network.

The load may comprise a second transmission line adapted to transmit alternating voltage from a generator, and the substation may be adapted so that the control means controls the switching of the switching devices to generate an output waveform for supply to the second network which is in phase with the phase of the voltage on the second network. Thus, two out of phase or even different frequency networks can be readily supply connected together to share power.

At least two substations may be connected in parallel between the supply line and the output load. This allows one substation to be removed from the network for repair as well as allowing the network to continue to function in the event that one substation fails.

A circuit breaker may be provided upstream of the or each substation. This allows the substation to be isolated from the transmission line.

The network may comprise a consumer electrical transmission and distribution network. The transmission line may supply voltage at say 145k volts or thereabouts, or perhaps 220k volts or more than 220k volts.

The load may operate at 36k volts, or perhaps 20k volts, or any value greater than either of these values.

Alternatively, the network may comprise a supply network for an electrical railway system.

There will now be described, by way of example only, one embodiment of the present invention with reference to the accompanying drawings of which:

> **Figure 1** is an illustration of a prior art passive substation for use in a power transmission and distribution network; and
>
> **Figure 2** is an illustration of a substation in accordance with the invention for use in a supply network.

Figure 1 is a schematic illustration showing a prior art at passive substation.

The substation illustrated in Figure 1 of the accompanying drawings 1 is connected between two three phase transmission lines 2a, 2b which carry 145k volt waveforms and four three phase output lines 3a,3b,3c,3d at 36k volts for onward distribution to a domestic supply network.

A spur line 10 connects the two input transmission lines 2a,2b together and includes two electrical isolators 11,12 which are provided between a centre tap 13 of the spur line and a respective transmission line. The isolators 11, 12 can be both opened (i.e. non-conducting) to completely isolate the centre tap 13 from both lines. Alternatively, one isolator can be closed (conducting) to connect the tap to one or other of the transmission lines 2a,2b.

The centre tap 13 provides a take off point for a supply line 20 to an input side of a three phase transformer 21. The output of the transformer, which is again three phase, is connected through a spur 22 to the four output lines 3a,3b,3c,3d.

A circuit breaker 23 and an electrical isolator 24 are connected in series between the transformer 21 and the centre tap 13 so that it can be isolated from the supply lines for repair or replacement.

Another circuit breaker 25 is provided downstream of the transformer 21 to isolate the transformer 21 from the output lines 3a,3b,3c,3d. Of course, in normal use the circuit breakers are normally open to allow current to flow in the transformer windings.

Finally, each of the output lines 3a,3b,3c,3d is connected to the transformer 21 through a respective circuit breaker 26,27,28,28 for extra protection.

The whole assembly of spurs, centre tap, transformer and circuit breaker/isolator is duplicated to provide two parallel connected circuits.

This is necessary to allow continuity of supply in the event that one transformer is shut down.

As shown, for a 145k volt supply with each transformer stepping the voltage down to 36k volts, the transformer typically needs to be able to handle 60 - 90 MVA (i.e. Mwatts) of power. They are therefore extremely bulky.

An alternative substation which its designed to replace that shown in figure 1 can be constructed in accordance with the principles of the present invention. Such a substation 100 is illustrated in Figure 2 of the accompanying drawings

The basic layout of the substation of Figure 2 is the same as for Figure 1 in so far as that it includes two identical half circuits. The main difference is that instead of a passive system employing a three phase step-down transformer each half circuit now includes a single phase transformer 101,102 with associated high frequency switching circuitry. Only one half of the circuitry will be described hereinafter for clarity. Where possible identical reference numerals to those used in Figure 1 will be employed.

A supply line 102 to the single phase transformer 101 from the transmission lines 2a,2b is connected to an input node 103 for an input switching circuit comprising a number of semiconductor switching devices such as IGBT'S. In practice, 3 input nodes 103 are required for the three phase transmission line.

The three input nodes are connected to the primary side of the single phase transformer 101 through a switching circuit 104 comprising a

number of semi-conductor switching devices (not shown) connected to form a bridge. The output side of the transformer is connected to the output load lines 3a,3b,3c,3d through a respective output switching circuit 105a,105b,105c,105d including further semiconductor switching devices (not shown).

The switching devices are controlled by control signals generated from a control unit 110. This unit (not shown) comprises a central processing unit which generates control signals to apply to the devices along contro lines 111. The processing unit constructs appropriate control signals dependant upon instructions from a suitable control program, and may also receive information from a measurement device which measures the current and voltage flowing along the input line 103 to the input switching circuit 104.

The three phase output is reconstructed from the single phase transformer waveform using pulse width modulation to control the switching devices of the output switc hing circuits so as to "reconstruct" a waveform of the desired phase and frequency. Additional smoothing circuitry is also provided to refine the shape of the output waveforms.

The transformer shown has two primary windings 112,113 and four output windings 114,115,116,117. This corresponds to one output winding for each output phase. In use, a first one of the input windings 113 is connected to the input switching devices which are then normally switched to produce the appropriate waveform in the primary winding. This is then replicated in the output windings.

In some instances, where a short break (of up to say one half cycle) in the supply voltage waveform occurs, the switching devices can be switched by

appropriate control signals to not generate a waveform in their associated primary winding. In this case, a back up energy store 200, such as a capacitor bank and which is connected to the other input winding 112 through a switching circuit can be used to provide a short burst of energy to fill-in the missing cycles. When normal operation is resumed, this bank can be recharged from energy taken from the supply lines.

By providing a solid state switching circuit in combination with a single phase transformer considerable operational benefits are achieved. Some of the advantageous features are set out below.

(1) Matched Sink Impedance control

The input impedance of the inverter is a measure of how the input current drawn by the inverter compares with the voltage applied to the inverter. The 3 phase voltages and currents may each be represented by a technique known as "Sliding mode control" by mapping the magnitudes of each of the three phases into single rotating vectors in two-dimensional space. It should be noted that a third number is generated which for a balanced 3-phase system should be zero. If the vectors for the voltage and current overlay each other the input impedance is resistive, if the current is in advance of the voltage then the input impedance may be regarded as a parallel RC. There will be a natural tendency for the current to lag the voltage due to the inductance of the transmission system. This will reduce the terminal voltage at the inverter and so a direct method of defining the current relationship to the source voltage to compensate for this can reduce transmission losses. This can be readily achieved by the

present invention by selecting appropriate control signals for the switching devices.

Considering a circuit in which the switching devices are connected in a bridge, the requirement is to control the switching of the bridge circuits so as to regulate the currents in the input inductances in a defined manner. Considering a 3-phase a.c. system, with a three arm bridge, there are eight permitted combinations of switching for the devices for each half cycle of the inverter. The switching state may be changed as zero voltage is reached on each half cycle of the resonant circuit both to maintain the resonant tank operation of t he "tank circuit" and to regulate the current in the inductors. If it is assumed the input voltage V_s varies very little over a half cycle period then the change in inductor current will ideally be given as:

$$\mathrm{Ai} = \frac{1}{\mathrm{Ls}} \int_0^{\pi} \left(V_s - V \sin\varnothing\right).d\varnothing$$

where V is either $+V_T$ or $-V_T$ the peak tank circuit voltage depending on the switch state. Mapping the change in currents for eight combinations of the switch states into the vector space gives six values as a hexagon with the two states representing all high or all low in the centre of the hexagon. The orientation of the hexagon relates to the position of the vector of the voltage in space and the magnitude of the hexagon relates to the magnitude of the input inductor L_s. This may be selected so that on selecting any particular switch state the resulting change in current is sufficient to track a reference current value with minimum error. Too

large a value and the possible change in current will not be sufficient to follow the reference, too low in value and the change in current at each step will be excessive, causing a high level of current ripple on the input.

(2) Fail Safe Power Protection

The strength of the use of high frequency transformer isolation is that, as the intermediate frequency rises the transient energy that can be transmitted between primary and secondary reduces. Thus by stopping the primary inverter circuit from switching, negligible energy can then be passed from primary to secondary and so a fail safe breaker action is provided. With normal breaker systems an action must initiate the breaking of current and so there is always doubt as to whether the breaker will operate correctly. With the system proposed the breaking of current is performed by preventing an action which is inherently more reliable and can be made "failsafe", i.e. the absence of any of a group of selected signals can inhibit the inverter operation with absolute certainty.

The system protection can be divided into those where damage may be caused to the substation system and those where damage may be caused to the system it is feeding. Because power transmission must have a high reliability the power feed is divided into various sub-circuits on the secondary which would normally control the flow of power. The use of the primary circuit to break power flow is only for catastrophic faults which would normally only occur within the inverter system itself.

The manner in which the inverters operate means that they should be rated to withstand the maximum current that will be present in the circuit they are supplying. This will be at a level very much higher than the rated current of the system which is based on r.m.s. current loading. The

loads are all transformer coupled and when a transformer is first switched on it momentarily sees an unbalanced supply and may saturate causing a high transient unidirectional current to flow. This will normally settle within a few cycles and it is important that the supply protection is able to discriminate between this occurrence and a fault current. The function $\int i^2 dt$ rising above a permitted level is usually applied to distinguish between a transient overload and a fault current. Thus the following protection can be provided by appropriate control of:

1. If currents drawn from the secondary circuit are above the maximum rating of the primary circuit the control may cause the primary circuit to inhibit, preventing further power transfer to the secondary side.

2. If currents from the load are above the rating of the secondary circuit or at a level set to be less than that for the primary circuit the control may cause the output voltage to reduce to maintain the current to within the maximum level. If this is maintained for an excessive time (e.g. > 100ms) that circuit must inhibit.

3. If the result of the function $\int i^2 dt$, where "i" is the current drawn from the load, rises above a permitted level then the secondary circuit must inhibit. The level can be set to represent the current level for the r.m.s. rating of the load system and must be high enough that standard short term transients do not cause the system to trip.

(3) Backup Energy Supply

The most common and reliable form of energy storage used in power electronics are either based on capacitors for small and medium amounts of energy and batteries for large amounts of energy. Both require a

variable d.c. voltage supply which can be varied to regulate the current inflow and outflow from the storage device. An example of such a system could operate from a secondary winding from the main transformer.

It will of course be appreciated that the above described embodiment is not intended to be limiting and that other embodiments of the invention are envisaged.

CLAIMS

1. A substation for use in a power transmission and distribution network comprising:

a single phase isolating transformer having at least one input winding and at least one output winding, an input solid state switching network comprising a plurality of semiconductor switching devices, the input switching network defining at least one input node for receiving an input voltage from the transmission network and at least one output node connected to the input winding of the transformer, an output switching network comprising a plurality of semiconductor switching devices, the output switching network being connected to the output winding of the transformer and defining at least one output node from which a voltage output can be taken from the substation, and a control means adapted to control the operation of the switching devices of the input and output switching networks to generate an output waveform at the output node from the input applied to the input node.

2. A substation according to claim 1 in which the control of the switches is dependent upon the condition of the input line and/or the voltage applied to the input.

3. A substation according to claim 1 or claim 2 which is adapted to operate over input voltages greater than 150k volts, or greater than 100k volts or greater than 10k volts.

4. A substation according to claim 1, 2 or claim 3 in which the control means includes measurement means adapted to monitor the

condition of the input voltage and modify or generate control signals for the switching devices dependent upon the measured value or values.

5. A substation according to any preceding claim in which the input switching device network comprises a bridge circuit having at least one input node for each phase of the input supply.

6. A substation according to any preceding claim in which the control means is adapted to control the switching of the switching devices so that a single substantially sinusoidal waveform is generated in the input side of the transformer whilst the switching devices on the output side of the transformer are operated to reconstruct one or more output waveforms of different phase from the transformer output.

7. A substation according to any preceding claim in which the control means in adapted to control the switching devices so as to produce at least one output voltage waveform which is independent of the input voltage waveform.

8. A substation according to any preceding claim in which the switching devices are arranged in relation to the transformer so that in the event of a failure of one or more switching devices or of the transformer or of the control means then power is not transmitted across the transformer.

9. A substation according to any preceding claim in which the control means is adapted to control the switching devices, at least of the input switching network, in such a way as to match the input impedance of the substation to the source impedance of the supply line.

10. A substation according to claim 9 in which the source impedance is controlled in real time by modifying the switching state of one or more of the switching devices under the control of the control means.

11. A substation according to any preceding claim in which the control means is adapted to control the switching devices to generate an output waveform that differs in phase from the input waveform.

12. A substation according to any preceding claim in which a limiting means is provided which is adapted to reduce the maximum output voltage produced in the event that the current drain exceeds a preset level.

13. A substation substantially as described herein with reference to and as illustrated in figure 2 of the accompanying drawings.

14. A transmission and distribution network comprising a transmission line for the transmission of electrical power from a generator, a substation in accordance with the first aspect operatively connected to the transmission line, and one or more distribution lines connected to the output of the substation for onward supply of power to a load.

15. A network according to claim 15 in which the load comprises a second transmission line adapted to transmit alternating voltage from a generator, and the substation is adapted so that the control means controls the switching of the switching devices to generate an output waveform for supply to the second network which is in phase with the phase of the voltage on the second network.

16. The network of claim 14 or claim 15 in which at least two substations are connected in parallel between the supply line and the output load.

17. The network of claim 14, 15 or 16 in which a circuit breaker is provided upstream of the or each substation.

18. The network of any one of claims 14 to 17 which comprises a consumer electrical transmission and distribution network.

19. A network substantially as described herein with reference to and as illustrated in Figure 2 of the accompanying drawings.

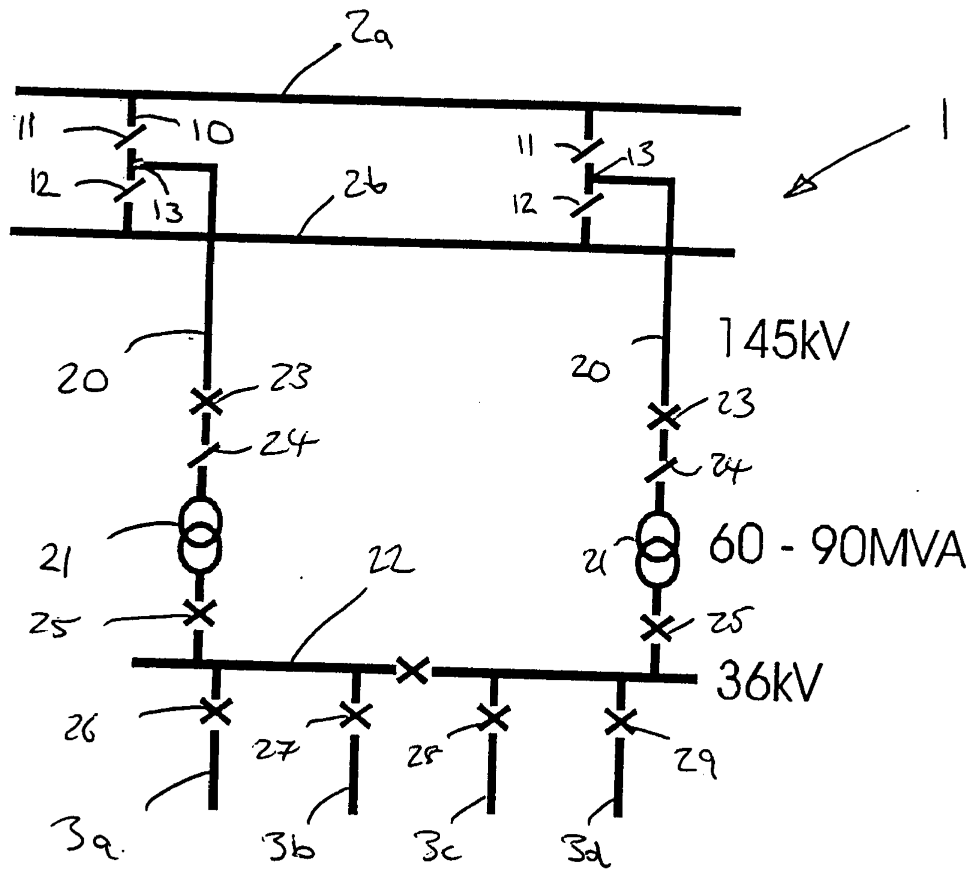
ABSTRACT

AN IMPROVED ELECTRICAL SUBSTATION

A substation (100) is disclosed for use in a power transmission and distribution network. The substation (100) comprises a single phase isolating transformer (101,102) having at least one input winding and at least one output winding, an input solid state switching network (104) comprising a plurality of semiconductor switching devices, the input switching network defining at least one input node for receiving an input voltage from the transmission network and at least one output node connected to the input winding of the transformer, an output switching network comprising a plurality of semiconductor switching devices, the output switching network being connected to the output winding of the transformer and defining at least one output node from which a voltage output can be taken from the substation, and a control means adapted to control the operation of the switching devices of the input and output switching networks to generate an output waveform at the output node from the input applied to the input node.

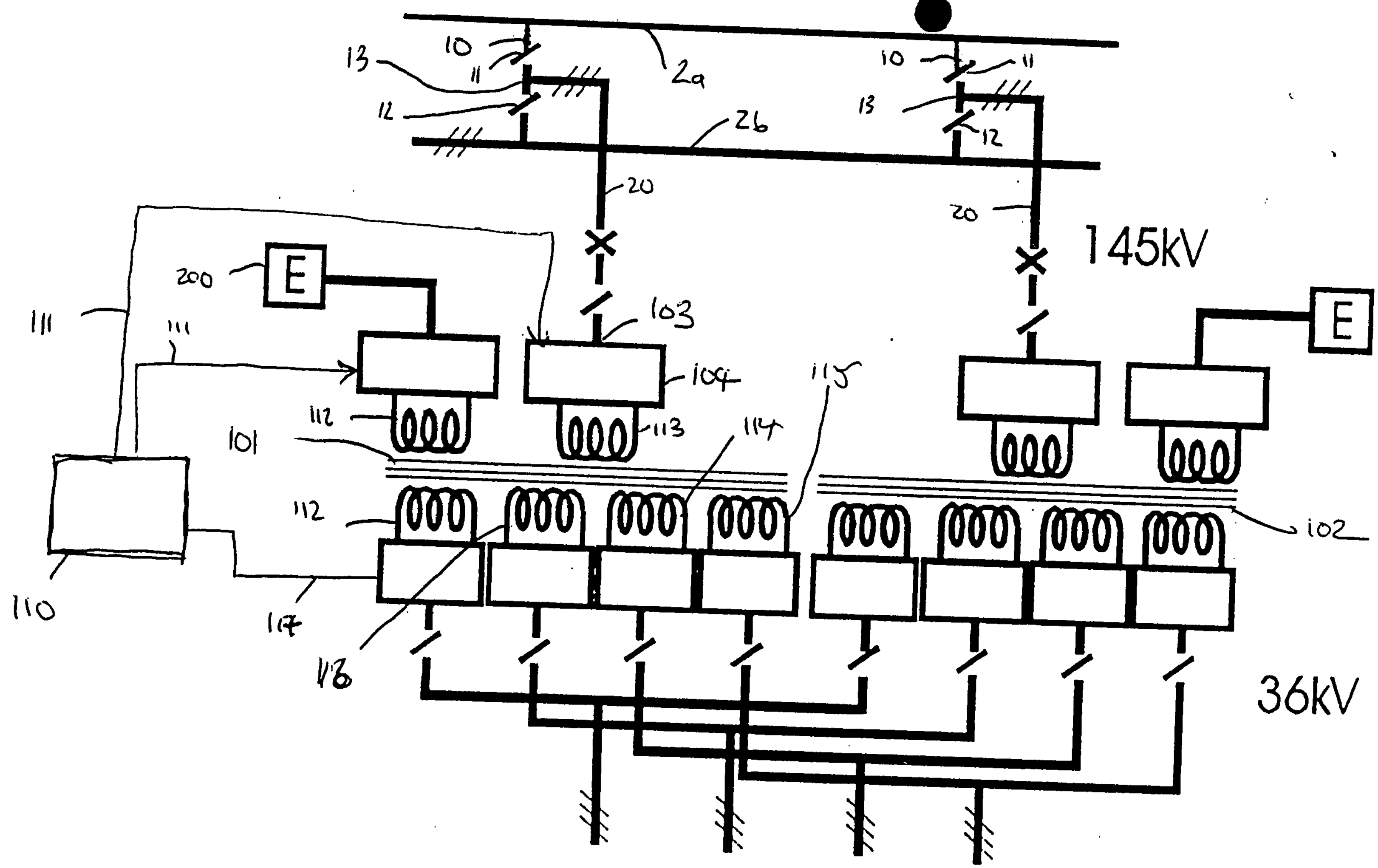
To be accompanied by Figure 2 of the drawings.

1/2



2a
2b
1
10
11
12
13
20
21
22
23
24
25
26
27
28
29
3a
3b
3c
3d
145kV
60 - 90MVA
36kV

Fig 1



10
11
12
13
2a
2b
20
145kV
E
200
103
104
111
112
113
114
115
116
117
101
102
110
36kV

Fig 2

PCT/GB01/01182

SB